Measuring echoes and propagation on the HF bands

Part 1

By H. de Waard (PA0ZX) and J.G.C. Niehaus (PA0FA)
Translated by Pieter Kloppenburg (VK1CPK) from VERON's 'Electron' of December '93

The Electron editors consider themselves fortunate to offer an article on a subject that many are interested in, but with which few have occupied themselves. In short, another facet of our hobby. The article is in two parts

Life on earth depends on the rays of the sun, and the sun continues to make our lives agreeable in many different ways. Without it, all life would soon disappear.

The formation of ionised layers at great heights (more than 50 km) through ultraviolet rays from the sun seems a small issue compared with everything else that happens in the universe. However, because of this, for example, long-distance communications have become possible.

For us Amateurs this is a fountain of inexhaustible joy, but also in general terms the possibility of reflection of radio waves by the ionosphere, despite the growing importance of satellite communications, remains of great importance.

In 1901, Marconi succeeded in establishing communications over a long distance between England and Newfoundland. In 1902, Heaviside and Kennelly postulated independently of each other the assumption that this was possible because radio waves at great heights are reflected by ionised layers. In 1925, Appleton proved the existence of ionised layers and determined the height of the important F-layer by measuring the delay of echoes of electromagnetic pulses. Since that time, echo measurements have become a standard method in research of the ionosphere.

A later practical application of using the ionosphere as a reflector for pulsed signals is the "Radar over the horizon". We Amateurs had to put up with these long-distance radars in the USSR of gigantic output powers in the form of "Woodpeckers" on our HF bands.

A conscious use of echoes via the ionosphere has never been an important issue in Amateur circles. This is not surprising; it is easy to believe that, apart from professional interest, not much can be achieved with it. Even so, Amateurs have experimented with this a long time ago. In QST of March 1952 (Ref 3), is a comprehensive article from W6QYT and W6POH in which the results are described of echo measurements in the 20-metre band. These were carried out in professional surroundings, namely at the University of Stanford, and with a peak power of 800 watt. This was probably not conducive to further home-conducted experiments.

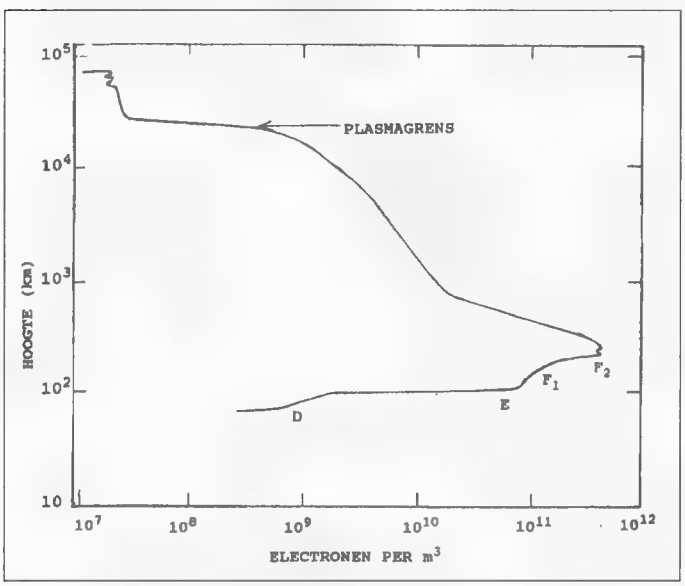

Figure 1: Height versus Electrons per m^3. Progress of ionisation density of the air above the earth's surface. The curve shows the concentration of free electrons depending on height, during the day, near low latitudes and during low solar activity. The height of the different layers (D, E, F_1 and F_2) of the ionosphere is also indicated.

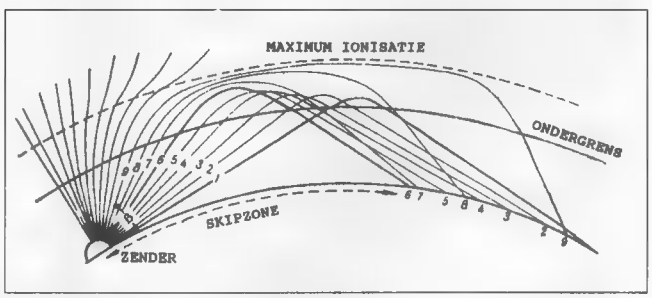

Figure 2: Schematic reproduction of the paths of electromagnetic waves that bounce once between the ionosphere and Earth, for different take-off angles b (Ref 6).

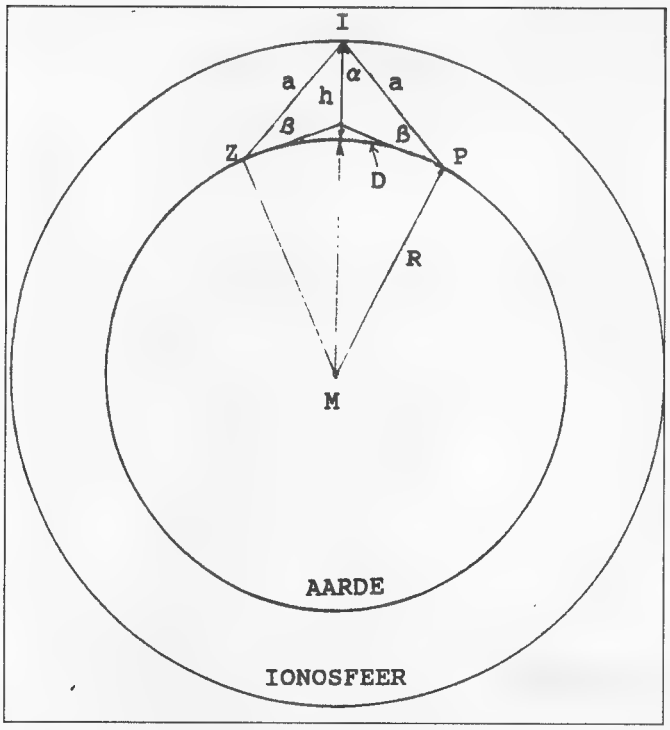

Figure 3: Diagram to aid in the calculation of algebraic magnitudes from measured echo delays. Z = Place of transmitter, I = Place of reflection in the ionosphere (the gradual bending of the wave is replaced by a sudden reflection, which is correct, provided a correction is made in the value of h, the height at which the reflection occurs), P = point of reflection against earth after one hop, a = distance between Z and I = distance between I and P. This distance follows direct from the measured echo delay t_E: a = (1/4)c/t_E (c = 300,000 km/s is the speed of light), R = earth radius, D = length of hop, h = effective height of reflection sphere with respect to earth sphere, b = take-off angle, a = acute angle of the electromagnetic wave in the ionosphere. Using the measured value of a, and the given values of h and R, all the other magnitudes in the figure can be determined.

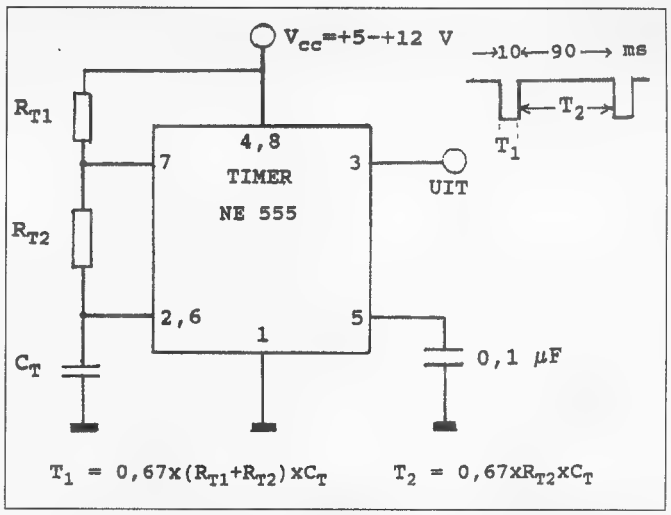

Figure 4: Pulser, based on NE-555 (PA0FA)
For T_1 = 10 ms (make) and T_2 = 90 ms (rest), use values of R_{T1} = 70 kW and R_{T2} = 18 kW, C_T = 1mF
For T_1 = 10 ms and T_2 = 190 ms, R_{T1} = 42.3 kW, R_{T2} = 3.3 kW, C_T = 4.7 mF.
Use 10-turn potentiometers for the given pulse duration for R_{T1} and R_{T2}, for example 100 kW and 20 kW.
V_{CC} is not critical; it must be of a value that ensures effective keying of the transmitter. Sometimes the correct pulse voltage can be obtained from the transceiver documentation. Check the pulse length after adjustment of V_{CC}.

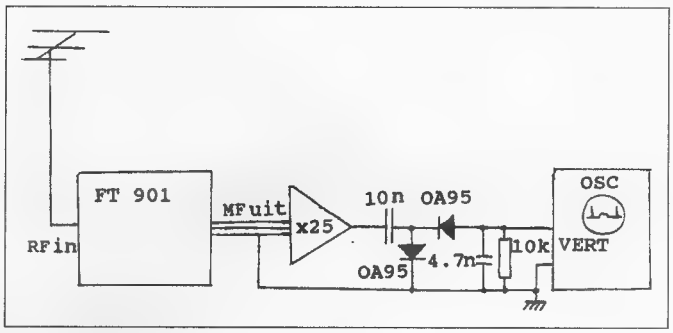

Figure 5: Interface between IF output FT-901 and oscilloscope (PA0ZX)

Nearly every PA operator, especially if he uses a beam, and probably a linear amplifier, is made aware of the existence of echoes via the ionosphere when he makes DX contacts. When he, together with another PA operator or a West European operator that he cannot receive directly, is in communication with a DX station that for both of them lies in approximately the same direction, for example the United States, he will often observe that the other European station is very readable. But when he turns his beam in the direction of the other European station, that signal disappears, provided that the distance between the European stations is at least 50 km. For a long time, this phenomenon has been called "Back-scatter". For this reason there exists, the widely held belief, but faulty assumption, that this scatter occurs in the ionosphere.

In December of 1991, the writers of this article, whose QTHs are about 40 km from each other, decided to use a pulsed signal to determine the distance at which Scatter appears. One station (PA0ZX) transmitted the pulses, and the other station (PA0FA) received the direct signal as well as that delayed by the ionosphere. In radar technology, this is called the bistatic method, which means separate locations for transmitter and receiver. Further research resulted in the development of a monostatic method, whereby transmitter and receiver are in the same place, and which can even be combined in a transceiver. This method is described under the heading "Monostatic long distance radar"; a cheap propagation monitor for the HF bands.

The results of the research invite us to continue with further development, and other Amateurs are warmly invited, to join us. An important conclusion from the research is that the returned signals have nothing to do with ionospheric back-scatter but that they are caused by reflection from the earth's surface and especially from sea waves and steep mountains, while the ionosphere acts normally as a nearly ideal mirror for to-and-fro radio waves. From measurements of the delay of echoes, the distance of the reflecting objects can be determined. You speak, therefore, of "echoes via the ionosphere", not of "scatter through the ionosphere". The

latter is wrong. This conclusion is not new; earlier echo measurements had led to this conclusion a long time ago. Even before the coming of weather satellites, an ionospheric radar system existed in the United States that measured the direction and height of waves in the Atlantic Ocean. With that, the development and movements of hurricanes could be observed (ref 4).

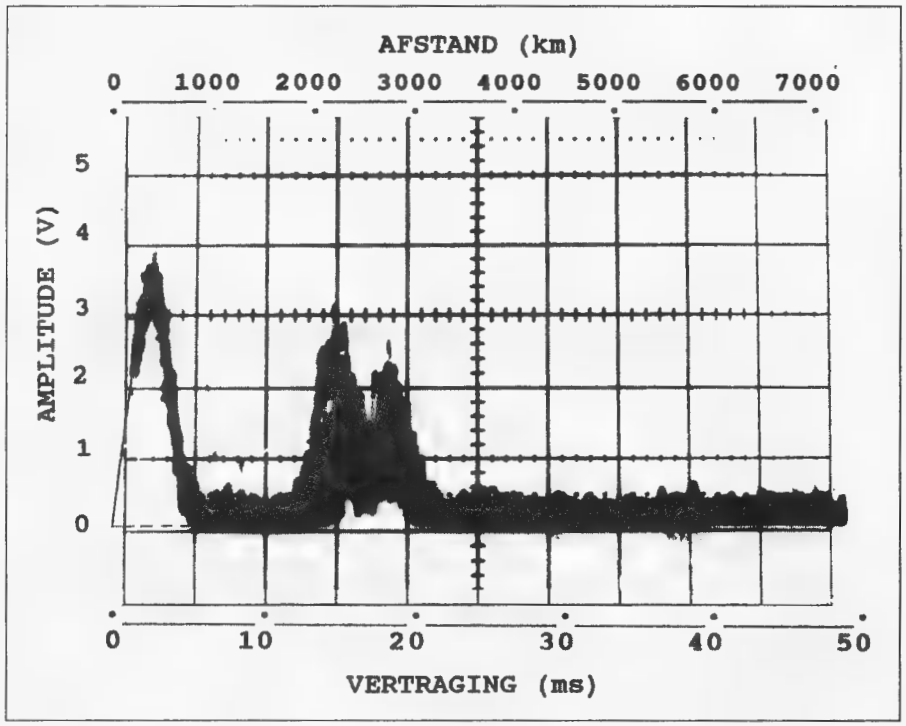

Figure 6: Amplitude versus Delay. One of the earliest echo photographs, recorded on 24-12-91 at 14:45 UTC. Frequency 28.96 MHz, IF bandwidth 3 kHz, beam heading 270°. Below the figure the pulse delay t_E, above the figure the one-way covered distance of the wave (2a = (1/2)c/ t_E). Recorded with Polaroid camera (shutter open for about 20 sweeps). Further details in the text.

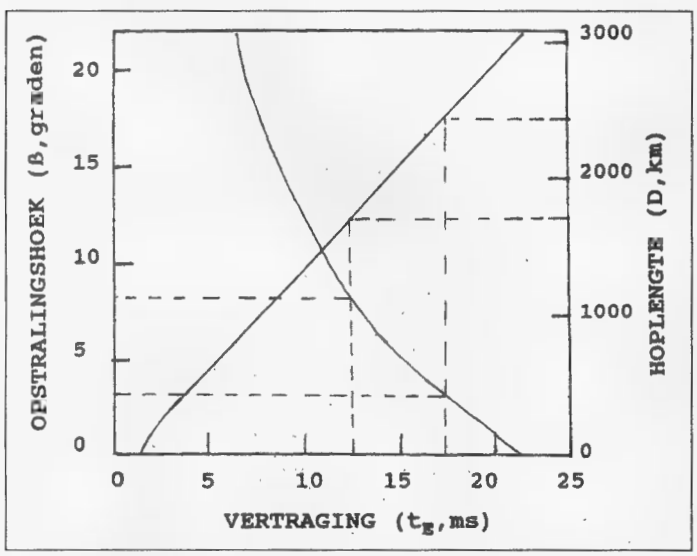

Figure 7: Take-off angle versus Delay versus Hop length. Calculated values of take-off angle b and hop distance D, as a function of the echo delay t_E, by an effective ionosphere height h = 200 km. The results of the measurement are drawn with broken lines in the figure.

Propagation of radio waves between earth and ionosphere.

Much is written about this matter, some in amateur accessible literature. We shall mention, therefore, only those aspects that are necessary for a good understanding for what follows.

The ionosphere stretches out between heights of 50 to more than 10,000 km above the earth. The region is penetrated by the rays, which the sun transmits in the far ultra-violet. Under the low pressure these rays release electrons from the molecules that are present there (mainly nitrogen and oxygen molecules), and the rays are thus eventually absorbed. This process is called ionisation, hence the name ionosphere. Closer to the earth, the only rays remaining are ultra-violet, close to the visible light spectrum and capable of frying us red or brown but unable to ionise air. Because some far ultra-violet wavelengths are absorbed better than others a certain layering of ionisation builds up and the strength of each is height dependent. Distinguished according to height are the D-layer (about 80 km), the E-layer (about 100 km), the F_1-layer (about 200 km), and the F_2-layer (about 300 km). The heights of these layers and the density of the free electrons per cubic metre are roughly indicated in Figure 1. Whether these layers can reflect the penetrating radio waves depends very much on solar activity, the frequency of the waves, and on the time of day and the year.

The most important layer for DX traffic is the F-layer and most often the F_1-layer. It is with this layer that we are concerned in this article. The bending of the electromagnetic wave in the layer is mainly caused by the presence of free electrons. We can compare this in some respects to the bending of light in glass or water, with the major difference being that the change in direction of the wave in the ionosphere is gradual and not sudden, as is the case with air and glass. Moreover, in the ionosphere the ability to bend waves, aka refractive index, is smaller than one, while that for light in a transparent material is always greater than one. We shall not go further into the physics background in this article, but to observe that in Nineteenth Century physics it was possible to

calculate the bending of waves in ionised gases, long before the existence of the ionosphere was proved through measurements. In Figure 2 (due to Al'pert) (Ref 6) are shown calculated tracks of waves that propagate through the ionosphere are shown.

We see that these waves are always bent back in the direction of the earth's surface. In the figure, wavelength and ionisation density are chosen such, that waves (numbered 1 to 9) with a sufficiently low take-off angle b return to the earth's surface. With an increase in angle b, the wave begins to be bend more strongly with increasing height until we see a wave (number 9) that keeps going horizontally over a great distance just below the height of maximum ionisation (the Pedersen wave, after the discoverer). When the angle b becomes even larger, the wave proceeds, after an initial bending in a horizontal direction, right through the maximum of ionisation, and above that bends upwards and disappears parallel to its original direction into space. As can be seen in Figure 2, the distance that can be bridged in one hop depends mainly on the take-off angle of the wave. The longest distance that can be bridged (with the exception of the Pedersen-wave) is with a wave with a 0° take-off angle, the shortest with wave number 6, a rather large angle. A zone is created around the transmitter within which the transmitter cannot be received, the so-called skipzone and beyond that a zone where the transmitter, after one reflection by the ionosphere, produces a strong signal. In principle, some scattering shall always occur by ionospheric action, but this scattered wave is so weak that it can hardly be observed with ordinary equipment.

The notion that plays an important role in the practical calculations of the possibility of communication via the ionosphere, is the highest frequency, whereby a wave with a small take-off angle b is just reflected by the ionosphere. This frequency is called the Maximum Usable Frequency (MUF). The greater the take-off angle, the lower the frequency whereby reflection occurs. With a take-off angle of 90°, i.e. straight up, the frequency of the wave that is just reflected by the ionosphere is the lowest, and called the critical frequency f_c. For many years it has been routinely measured in many places around the world. A relation exists between the MUF and f_c as follows:

$$F_{MUF} = f_c / \cos a \quad (1)$$

where a is the angle at which the wave approaches the ionosphere (indicated in Figure 3). This angle can be calculated from the take-off angle and the height h where the reflection occurs. Of importance to us is the maximum frequency whereby a wave hits the

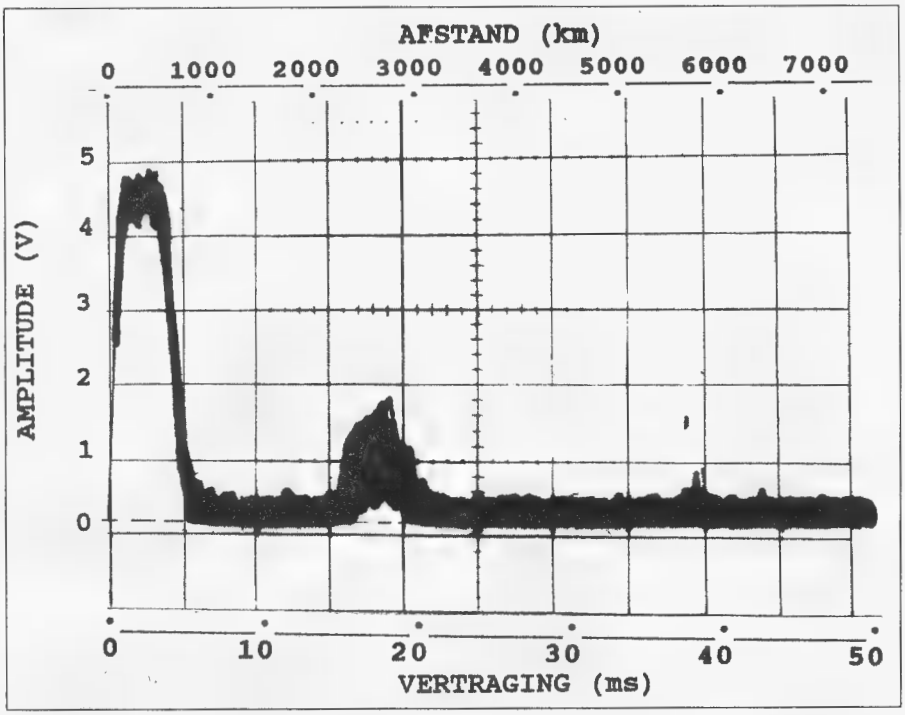

Figure 8: Amplitude versus Delay. Echo from Southerly direction, probably from the Atlas Mountains in Morocco, North Africa, at a distance of 2200 ± 100 km. Recorded on 29-12-91 at 13:15 UTC. Frequency 28.96 MHz, IF bandwidth 3 kHz, beam heading 180°

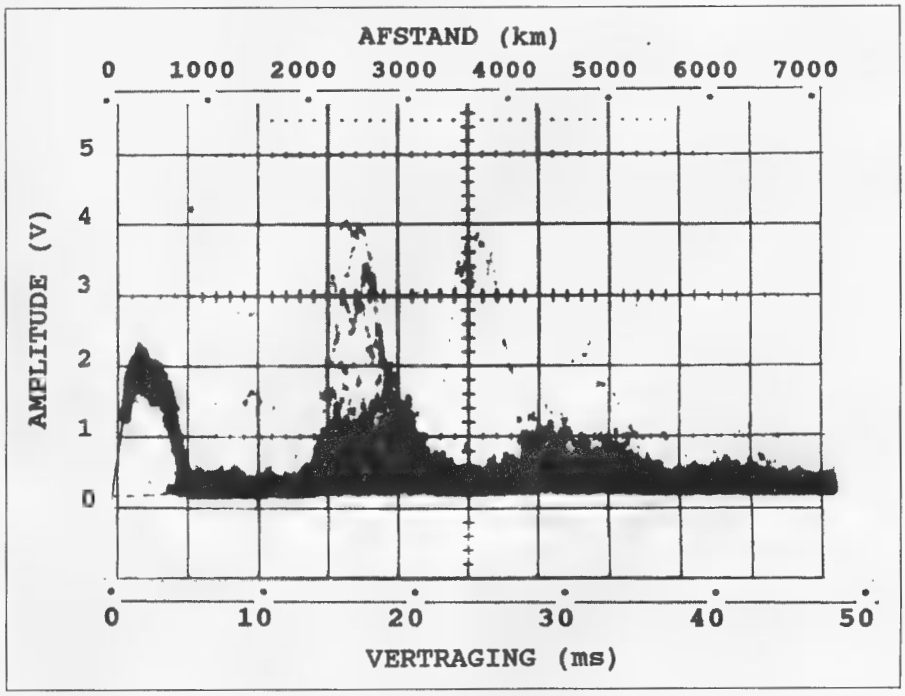

Figure 9: Amplitude versus Delay. (Triple?) Double echoes from the ocean, recorded on 29-12-91 at 13:30 UTC. Frequency 28.96 MHz, Beam heading 280°. Other details as for Figure 6.

ionosphere with a small angle and is still reflected by it, because that is what we use when making long distance connections. For h = 200 km and a realistic take-off angle, b = 8^0, a is 72^0, $f_{MUF} = 3.2 \times f_c$.

The critical frequency depends on the degree of ionisation of the ionosphere, which is determined by the sun's activity and the time of day (at night, f_c is reduced by a factor of two or three). During a period of maximum solar activity the critical frequency can increase to f_c = 13 MHz, thus f_{MUF} is 40 MHz, and the 10-metre band is wide open.

There are two important possibilities for propagation across distances much greater than single-hop. In the first place through multiple hops, in the second place through a wave which propagates over a long distance inside the ionosphere (the Pedersen-wave). The first possibility shows itself when we make contacts with Amateurs in the United States, the second when comparatively reliable contacts are made with Amateurs in Australia and New Zealand.

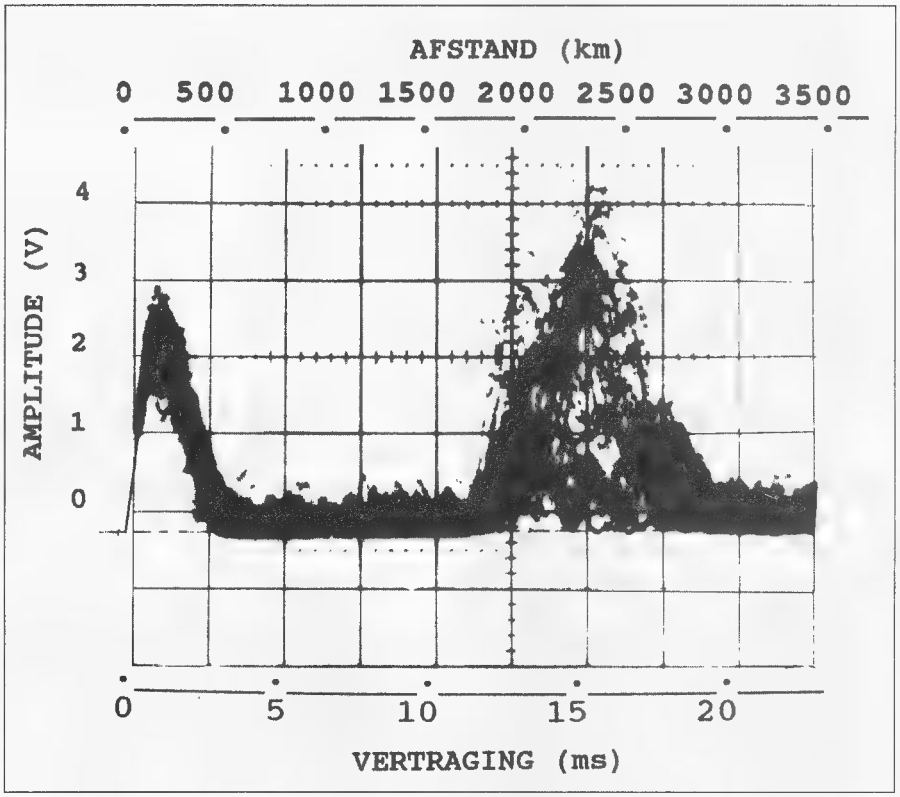

Figure 10: Amplitude versus Delay. First echo from the ocean, on a smaller time scale. Recorded on 16-1-92 at 11:40 UTC. Frequency 28.96 MHz, IF bandwidth 2 kHz, Beam heading 285^0. Other details as for Figure 6.

Echo measurements with a "bistatic radar".

The appearance of echo signals during DX-contacts, as a consequence of which stations in the same area (but not within reach of each other) can receive one another with signal strength of S3-S7 when their beams are pointing in the same direction, led us to the question of where those echoes actually come from. Because the answer "Ionospheric Scatter" that experts gave us in the first instance wasn't very convincing, we decided to conduct a test. The distance between our QTHs (Gieten - Groningen) is about 30 km and was therefore favourable, because the signal strength of the direct received signal and the echo signal (when the band is open) were comparable; with pointing angles of 270^0 for both stations, it was about S-7. We found that the sound had a hollow ring to it, as in an empty room with hard surface walls. Within a few days PA0FA had made up a pulser (Figure 4) that could be plugged into the Key-input of his transceiver (ICOM IC765), PA0ZX connected the IF-output of his Yaesu FT901 via an IC amplifier to a detector (Figure 5), which turned the received CW signal from PA0FA (with a pulse duration of 1 ... 5 ms and pulse period 50 ... 200 ms) into a row of positive-going pulses that were applied to a scope with a calibrated timebase. Directly received pulses trigger the scope. Usually, the timebase is set for 5 ms per major division on the scale. The IF bandwidth of the receiver can be varied from 1 to 4 kHz.

We used a Polaroid camera to record the scope display, and manually operated the shutter at speeds of between 0.5 ... 1 second, so that with a pulse frequency of 20 Hz (50ms period), 10 ... 20 successive sweeps were recorded on the film. One of the first results, when pulses were transmitted on the 10-metre band (on 28.96 MHz) is shown in Figure 6. The direct pulse is on the extreme left with a half-height width of 3 ms and a rise time of about 2 ms. Further to the right we see echo pulses with a delay of between 12 ... 17 ms, thus with a spread in time of 5 ms, and also with large fluctuations in amplitude. When you look at the scope screen in real time, you'll notice a very turbulent display. Because the propagation speed of the wave is 300,000 km/s (the speed of light), one millisecond of delay corresponds with the wave covering a distance of 300 km. Therefore, a delay of 12 ... 17 ms corresponds with a distance of 3600 ... 5100 km. Because the wave travels to and fro, the actual distances between antenna and obstacle is half of this, that is 1800 ... 2550 km. The distance scale is annotated on the top edge of the screen. In Figure 2 there are two obstacles that could cause these echoes: the ionosphere at point 1, at distance a, and the earth at point P, at distance 2a. Calculations reveal that a distance a = 1800 km even with a take-off angle of b = 0^0 would correspond with a height h = 400 km, but at such a height there is no reflection. We must therefore conclude that we see an echo from the earth's surface. The first possibility occurs after one hop near point P. The to-and-fro distance covered by the wave between the ionosphere and the earth's surface is then 2a. That is longer than the distance measured over the earth's surface. Using Figure 3 and the Pythagorean theorem you can calculate

that when the wave is at height h = 200 km (F_1-layer) it is reflected and the hop distance is D = 1700 ... 2200 km. For the measured value of 2a and the given value h = 200 km we can also calculate the take-off angle of the wave of which reflected signals are observed, these lie between 3° and 8°. In Figure 7 are the results shown graphically of the calculations of take-off angle and hop distance as a function of the measured delay. Those calculated values are indicated with broken lines.

It is interesting to observe that from the maximum take-off angle at which echoes are still received, and the height of the ionosphere, an estimate follows also for the critical frequency f_c in comparing (1) with b = 8° and h = 200 km, you'll find from Figure 3 with Pythagoras: a = 74° and then from comparison (1): $f_c = f_{MUF}$ and cos a = 28.96 x 0.28 = 8.1 MHz. The inaccuracy of the measurement of the echo delay and the uncertainty of the value of h, lead to an error of about ± 1 MHz in this value of the critical frequency.

From where do these fluctuating echoes exactly come from? We saw from the large variations in time delay that they come from an area of substantial dimensions: about 2200 ... 1700 = 500 km deep in the direction of the wave. The half-power beam width angle of our beams are about 30°, and this provides, at a distance of 2000 km, a width of 1000 km perpendicular to the direction of the wave. For the chosen beam heading of 270°, the center of this area lies approximately at 27° North and 46° West, which is in the North-Atlantic Ocean, about 900 km North of the Azores.

If the ocean were flat in the area from which the wave is reflected, the wave would continue in a southwesterly direction and begin a second hop. On the surface of the ocean exist large and small waves; these have a changing angle with the horizontal surface. At various places and times, these angles become great enough to reflect the radio waves back into the direction from which they came. This effect is put to good use by radar systems that locate and track hurricanes, as described by Villard in QST (Ref 4). With such a system, even windspeed and force can be determined in a large number of places in areas of the ocean. The echo signal is always at least four S-points weaker than one that is returned after one hop (think of the signal strength of stations in Spain). This means, that, with ocean reflections, only about 1% of the electromagnetic energy (-20 dB) returns to us.

Now back to our own measurements. In December 1991 and January 1992, we made a large number of records of received echoes. Often in the 10-metre band, but also in the 15- and 20-metre band. A few special ones are reproduced here as follows. In Figure 8 we see a reflection from a Southerly direction (beam headings PA0FA and PA0ZX are both 180 °) of pulses transmitted on 28.96 MHz. These reflections are 'quieter' and of shorter duration than reflections from the ocean. From the echo delay (15.5 ± 0.7 ms) we see a hop-distance of D = 2200 ± 100 km, in Southerly direction. When we look in the atlas, we see the Atlas Mountains in Morocco, North Africa, which stretches out in an East-West direction. One high peak in these mountains lies 2275 km South of Groningen (latitude difference 53 North - 32.5 North = 20.5). The reflection disappears when the beam is turned 30 °.

In Figure 9, the beams are turned again to the West with a heading of 280 °, a frequency of 28.96 MHz, and an IF bandwidth of 3 kHz. Here, adjacent to the first reflection (12 - 20 ms) we see the second one distinctly (24 - 32 ms) and possibly something of a third one (38 -?). The second reflection at distance D = 3400 to 4600 km corresponds with two hops, the third one would agree with three hops, but this one lies deeply in the noise. In Part 2 we shall see how making the IF bandwidth much smaller, results in an improvement in the signal to noise ratio and late arriving reflections becoming more visible.

We have observed that the structure in time and amplitude of the echo signal varies strongly from day to day. Not seldom there are two peaks visible on the scope with steep wavefronts in the right direction (perpendicular on the transmit direction) as shown in Figure 6. These two peaks are separated by about 600 km. In addition, the difference in amplitude between the two peaks can vary strongly from day to day. While these in Figure 6 are a maximum of 0.8, in Figure 10 the variation is nearly 1.5. This could be caused by the amount of disturbance on the ocean surface, but also because of variations in the received signal strength because of changes in atmospheric conditions between PA0FA and PA0ZX

Postscript

This article was published earlier in *Electron* of September 1993, but with incorrect captions of the figures. Part 2 was published in *Electron* of October 1993

References

1 D. Rollema, Electron, Vol. 37 (1982) Page 562

2 D. Rollema, Electron, Vol. 40 (1985) Page 61

3 Instantaneous Prediction of Radio Transmission Paths, QST March 1952, page 11

4 Over-the-Horizon or Ionospheric Radar, QST, April 1980, page 39

5 Encyclopaedia Britannia, 1973/74 Vol. 9 page 813

6. Radio wave propagation and the ionosphere. Ya. L. Al'pert (Consultants Bureau, New York, 1963) page 316.

7 L.c. ref. 6, page 308

Other references:

Long-Delayed Echoes ... Radio's "Flying Saucer" Effect, QST May 1969, page 38

nr

Snail mail address for contributions: **The Editor**
Amateur Radio
34 Hawker Crescent
Elizabeth East SA 5112

email address for contributions:
edarmag@chariot.net.au

Measuring echoes and propagation on the HF bands

Part 2

By H. de Waard (PA0ZX) and J.G.C. Niehaus (PA0FA)
Translated by Peter Kloppenburg VK1CPK from 'Electron' of October 1993

In Part 2, PA0ZX and PA0FA start with the Monostatic long-distance Radar, a cheap propagation monitor for the HF bands and how this can be used by Radio Amateurs.

Measuring propagation

On the basis of experiments described in the previous paragraph, refer to the December 1993 issue of 'Electron', a simple instrument is developed with which we can determine if there is propagation.

Many Amateurs ask themselves sometimes "What are the conditions at the moment". The normal way to find out is to listen on the various bands, or call "CQ-DX" and then wait to see if something comes up. This action does not tell you if the band is open in some other direction! In silence, the wish is often expressed "Apart from my ohm-, volt- and amp meter, I could do with a propagation meter".

The measurement of propagation at an arbitrary moment was until now only possible to be performed by Government departments and scientific institutions. To ordinary mortals it seemed to be an enormous effort to get the required information at any particular time.

It will become evident from the following that with presently available means, much can be done about this, without denying the benefit of predictions and the youngest branch of Amateur activities, packet clusters.

Monostatic Radar

After the tests described in previous paragraphs with separate transmitter and receiver, the bistatic radar, the question came up whether it was possible to combine transmitter and receiver in one and the same place. One step further is the common use of a directional antenna for transmit and receive. After this, we realised that we could work with one transceiver, provided a number of conditions were met. In this way, monostatic radar was realised. Based on previous experiences, the following starting points were formulated:

1. The transmitter must output pulse-shaped signals
2. The changeover from transmit to receive must happen very quickly.
3. The received echo must be able to be observed on a simple oscilloscope.

This was carried out by PA0FA as follows:

1. The NE-555 was wired as a pulser. Refer to Figure 3 (page 11, AR December/January). At the Key-input of the transceiver appear pulses at 10 Hz, 10 ms wide, with each pulse followed by a rest period of 90 ms. As a consequence of an in-built circuit delay, the transmitter output consisted of pulses with a width of 3 ms in this instance (ICOM IC-765).
2. The short HF pulse is only generated when the transceiver is in the "full break-in mode". The dead time right after the pulse is transmitted is about 20 ms, which when added to the transmit pulse of 3 ms, gives a minimum delay of 23 ms.
3. The two-channel scope is triggered through channel A by the pulser, and the audio signal is connected to channel B. The scope's timebase is usually set for 10 ms/div. When a single channel scope is used, the trigger input is used for pulses and the audio signal is connected to the Vertical Input.

In the previous paragraph we mentioned that the first echo returns after 12 to 18 ms, these cannot be seen using this particular transceiver. Although this is very unfortunate, the monostatic tests were continued with, because the results were sensational from the beginning. Where in the bistatic setup the first echo was clearly defined and the second one reasonably so, in the monostatic setup the second echo was also clearly defined and well above the noise. To be able to observe more clearly the reflections from locations much further away, it was necessary to improve the receiver's signal to noise ratio. This was not a great problem with the built-in narrow-band filters. The standard IC-765 is equipped with a 500 Hz CW filter. An optional 250 Hz filter was also installed. With each transmitted pulse, we now received nearly always-different reflections from points on the earth's sphere, at ever increasing distances. (See Figure 11)

Observations with the Monostatic long distance radar

Left, on the scope's screen, is a pulse that is generated by the "Side-tone" oscillator (BFO). The length of this pulse compares with the transmit time of the HF pulse. About 20 ms after the trigger pulse, the receiver recovers to its normal sensitivity (AGC on fast). During the time interval until the next pulse is transmitted, any echoes present can be observed (Figure 11). The sound that comes from the speaker is first the short side-tone simulation of the transmitted pulse. After that you can hear the reflected signals that are made audible by the BFO facility. The Pitch-Control should be used to make these signals have a high pitch, to get a well-defined display on the scope. You can expect the first echo to appear after 25 ms probably with fluctuating amplitude.

It is recommended to keep the noise level confined to within one major division on the scope screen. The returning echo signals can then be observed in the correct ratio above the noise level. Recognisable Echoes have been observed with delays of 65 ms after the transmit pulse. With some doubt, it is better to say, "Saw no echo". Naturally,

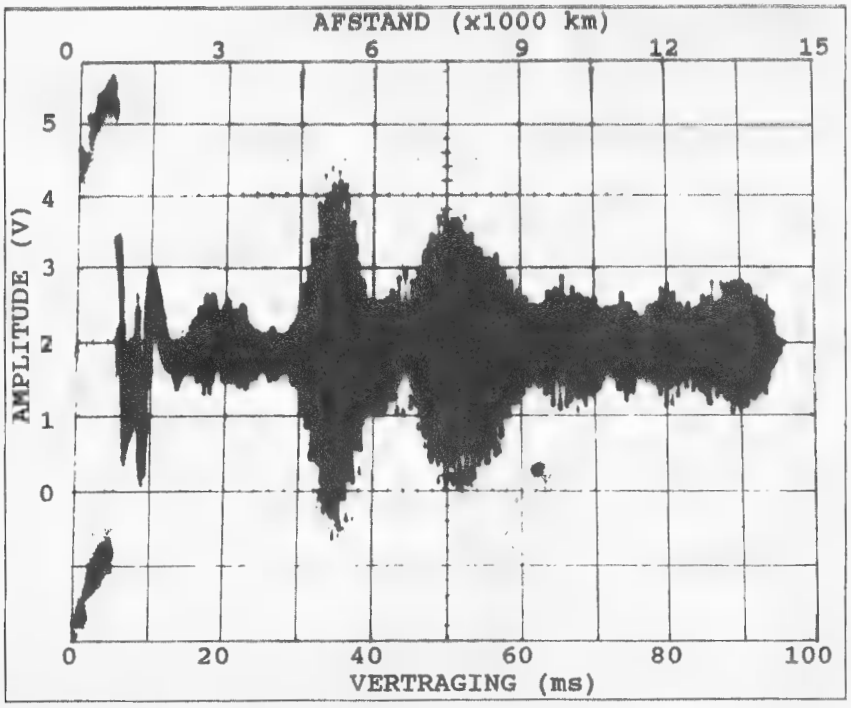

Figure 11: Record of echoes using monostatic radar (PA0FA). The sinus-shaped signals come into existence when the BFO is switched on. Left, the transmitted pulse, followed by a few decaying oscillations; after a dead time of about 20 ms, in which the first echo appears, we clearly see a second and a third echo. Recorded on 17 September 1992 at 15:20 UTC. Frequency 21.23 MHz, Bandwidth 250 Hz, Beam heading 100°.

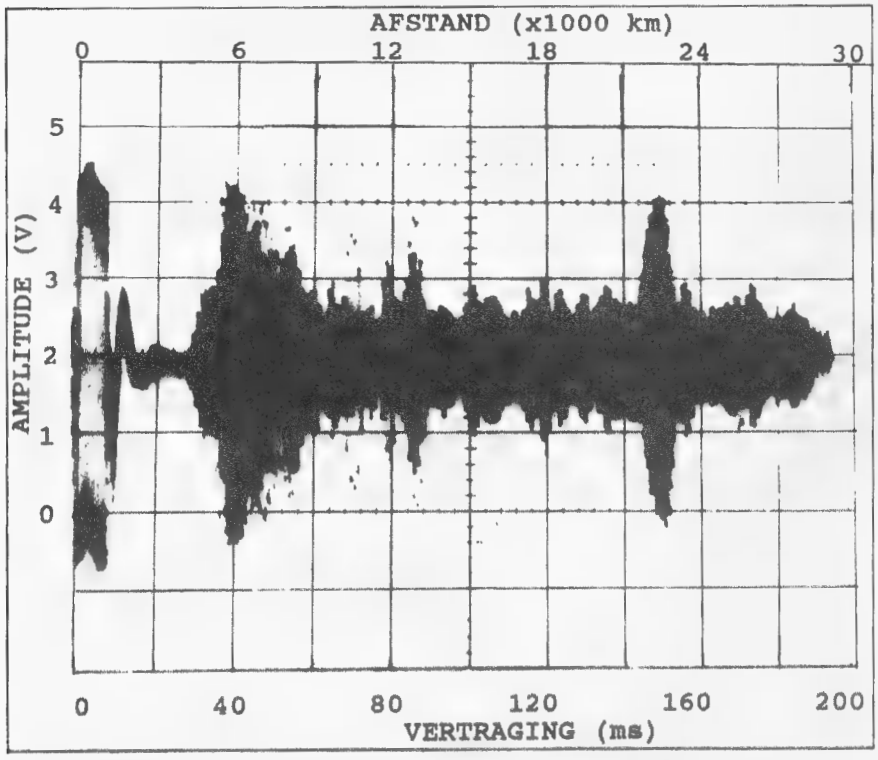

Figure 12: Record of echoes using monostatic radar, using a longer time scale (PA0FA). Here you can also see, apart from the 'normal' return, a sharp peak with a delay of about 140 ms, coming from a pulse that went once around the earth (not an echo, for which the scale is valid). Recorded on 18-10-92 at 08:20 UTC. Frequency 21.42 MHz, Bandwidth 250 Hz, Beam heading 230°.

the presence of echoes is completely dependent on propagation in a particular direction. No echo, no propagation.

Distinguishing between echo and noise can give problems. With noise, we mean any signal that does not result in recognisable or regular repetitive echo signals at the correct frequency. It is possible to make a good distinction between a repetitive echo and noise by detuning the receiver by about 1 kHz using the Receiver Incremental Tuning (RIT) control, and leaving the transmitter unchanged. The real echo will disappear then. Another possibility is changing the heading of the antenna; there are always directions from which no echo returns.

Pulse length and Pulse-Repetition-Frequency (PRF)

The transmitted pulse must be long enough to drive the output stage to maximum power, but short enough to quickly observe a reflection. The pulse length should not be longer than 10 ms, since the first echo can return to the receiver after 10 ms. The PRF seems to be an arbitrary business. It would be rather sensible on the one hand to match it to the position of the scope's timebase switch, but on the other hand taking account of the time required by the fourth echo to return.

With "Short Path" echoes, a PRF of 20 or 40 is the most useful one. (Scope owners would set the timebase switch to 5 ms/div or 10 ms/div.) With an PRF of 10 (20 ms/div), a certain amount of flickering shows up on the screen, but this can be overcome by setting the timebase switch back to 10 ms/div. Use of a timebase set to 20 ms/div and a PRF of 10, provides the opportunity of observing "Long Path" echoes, as well as observations of propagation around the earth.

A tour around the world in 140 milliseconds

During tests with the objective of detecting "Long Path" echoes, a PRF of 10 was used. At different times and from diverse directions a signal was observed with a delay of about 140 ms (Figure 12). Very soon, it was realised that the transmitted pulse had made a tour of 40,000 km around the globe. The signal came through the back of the antenna

suffering an added attenuation of 20 dB because of it. No further argument is necessary to realise that with two rotatable antennas interesting observations can be made.

Disadvantages of echoes on the bands

We have seen in the foregoing which are the useful and enjoyable aspects that echoes can provide. We can study the behaviour of the ionosphere, we can check in which direction DX contacts can be made, and we can often make contacts with Amateurs within the skipzone. This last advantage becomes known when, from a limited area, more stations want to contact a DX station.

However, we must also deal with the less pleasant aspects. Problems can develop for AMTOR contacts. When the other station receives a relative weak signal during the contact, a large number of ERRORS can develop because the control signal of the other station is overrun by that station's own echo signal. How serious this is depends on the time taken until the station's own echo signal returns, on the currency of the control signal from other station to ones own station, and on the signal strength of the station's own echo relative to the signal of the other station.

It can happen, that, judging by the sound, an excellent Amtorlink produces a large number of repeats because of the echo effect. Generally, you would not recognise this immediately.

An example with numbers can give somewhat more insight. Assume that the AMTOR timing details are known. Imagine an AMTOR contact between two stations separated by a distance of 3000 km. We call A the master and B the slave. The delay from A to B is 3000 (km)/300,000 (km/s) = 10 ms. After receiving a "Block" from A, B returns a control block back to A. The beginning of this control block arrives at A after 20 ms. After 25 ms A's own *second echo* returns. It takes little imagination to realise, that a collision of sorts can take place between the control block and the echo. Even if only one bit of 10 ms comes across faulty, the whole block is rejected and a request for a repeat is send out. Prolonged faults can result in time-outs.

The licence conditions

Naturally, on-air manners have to be upheld at all times. You must realise that other stations in general do not completely understand what all that ticking is about. Please adhere to the following rules:

- Ask first if the frequency is in use
- Give clear station identifications at regular times
- Mention that you are conducting a ionospheric test
- Don't make your transmissions longer that necessary
- Don't use too much output power; peak power of 100 watt is sufficient

When switched to "CW", the bandwidth of the transmitted pulses is limited in every commercial transceiver by a filter. From the rise and descent times of the received pulses (using a receiver with a wide bandwidth) we are able to conclude that the transmit bandwidth in our case is only about 500 Hz.

Conclusions

This article has described a number of circuits to aid our echo-experiments on the HF bands and the results that were obtained. Its most important objective is to show that with a few extra simple circuits, a new dimension can be added to our hobby. Not all the experiments that were made have been described, in particular not the coming into being in the morning and the disappearance at night, of propagation on the 10 metre band, caused by the occurrence of sunrise and sundown. Also the small differences in delay time of echoes on various bands and the change in this delay during the day have not been accurately analysed. Another, mysterious appearance is the occurrence of echoes with very long delays: many seconds. Scattered over many years, something has been written about it, but there is still no satisfying explanation of the phenomenon. With Amateur patience and a slow-running tape-recorder, something new can still be discovered. Our method of echo recording on photographic film or on audiotape is electronically seen, very primitive. Modern memory chips and digital data processes provide the means for getting much more quantitative details.

There is still much original detective work to be done. The professionals have not seen everything. The variation of the adventures which electromagnetic waves in the ionosphere and on the freakish, reflecting earth surface can experience is nearly unlimited.

FEDERAL WIA CONVENTION

APPOINTMENT TO FEDERAL POSITIONS

The WIA Federal Convention and Annual General Meeting of the WIA will be held in Adelaide on 4, 5 and 6 April 2003.

At this meeting, a number of positions will be filled. Nominations from interested persons must be received by the Federal Secretary at the registered office of WIA Federal in Melbourne no later than **close of business on 21 February 2003.**

The positions are:

(A) Federal Executive

President
Directors (3 positions to be filled)
Company Secretary

(B) Officers and Coordinators

Editor "Amateur Radio" magazine
Publications Committee
WIA/ACA Liaison Committee
IARU Region III Liaison Officer
ITU Conference & Study Group
Federal Web Page Coordinator
Chairman Federal Technical Advisory Committee
Federal Education Coordinator
Federal Historian
AMSAT Coordinator
Intruder Watch Coordinator
Federal Contest Coordinator
Federal Awards Manager
Federal WICEN Coordinator
International Travel Host
ARDF Coordinator
Federal QSL Manager
VK9/VK0 QSL Bureau
QSL Collection Curator
Videotape Coordinator

Nominations received direct will be considered but preference is likely to be given to Divisional nominees

Peter J. Naish, VK2BPN
Federal Secretary